ORIGINAL ARTICLE

Spinal extension exercises prevent natural progression of kyphosis

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Abstract

Summary The angle of kyphosis increases with age with the most rapid increase occurring between 50 and 60 years. The progression of kyphosis was prevented in women ages 50–59 years who performed extension exercises three times a week for one year.

Introduction The purpose of this study was to (1) measure the progression of the angle of kyphosis with age and (2) determine whether spinal extension exercises prevent progression of hyperkyphosis in women 50–59 years of age.

Method Part 1: Cross-sectional study of changes in posture with age, determined by measuring spinal curves in 250 women 30–79 years of age. Part 2: One-year prospective, descriptive analysis of the effect of extension exercises on posture in women 50–59 years of age. Depth of the cervical curve (CD), area under the thoracic curve (TA), and height were measured using a device developed at Kansas University Medical Center. Changes in CD and TA in

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B. E. Johnson Department of Internal Medicine, Virginia Tech-Carilon College of Medicine, Roanoke, VA, USA women compliant with extension exercises were compared to those in non-compliant women.

Results Kyphosis increases with age in healthy women, with the greatest difference observed between women 50 and 59 years of age. The progression of kyphosis was greater in women who did not perform extension exercises compared to those who performed extension exercises three times per week for 1 year. The difference in change in CD and TA between the two groups was highly significant (CD p=.0001, TA p=.0001).

Conclusions Kyphosis increases with age in healthy women. In this study the greatest difference in the angle of kyphosis was observed between the fifth and sixth decade. Exercises which strengthen the extensor muscles of the spine can delay the progression of hyperkyphosis in the group included in this study, i.e., women 50–59 years of age.

Keywords Extension exercises · Kyphosis · Prevention

Introduction

A recent review of hyperkyphosis in older persons emphasized the need for a more complete understanding of the causes, consequences and treatment of this condition [1]. We present here the results of a pilot study which examined the changes in the degree of kyphosis with age in a group of postmenopausal women without fractures, and the effect of extension exercises on the progression of kyphosis.

First, it is important to understand the development of spinal curves in the normal life cycle. The function of the human spine is to give support in the upright position, balanced against gravity, and to allow movement. There are three superimposed curves in the upright spine of the normal adult: cervical lordosis, thoracic kyphosis, and lumbar lordosis. All three curves must be intersected by the line of gravity to remain balanced. In the thoracic spine, the line of gravity falls in front of the vertebral body, thus exerting force on the anterior portion of the vertebrae. The direction of the gravitational pull creates the physiologic kyphosis.

Spinal curvatures change throughout the life span [2]. In infancy there is a "C" curve, one continuous curve from occiput to sacrum. By 6 months the cervical lordosis has appeared, and in adults we see a cervical lordosis, thoracic kyphosis and lumbar lordosis. Significant changes in spinal alignment again occur with advanced age with loss of lordosis in the cervical and lumbar regions and a significant accentuation of the thoracic kyphosis. The spinal curve returns toward the "C" curve of infancy.

Kyphosis is defined as an angular curvature of the spine with the convexity of the curve being posterior in the thoracic region. An increasing angle of kyphosis is a common problem in aging women. The prevalence and incidence of hyperkyphosis in older persons is estimated to be 20%-40% [3, 4]. Changes in the spinal curve in the elderly cause both physical and psychological distress due to changes in balance, posture and self image; difficulty fitting clothing, musculoskeletal pain due to muscle spasm, tendency to fall, and changes in articulation of the apophyseal joints of the vertebrae [1–9]. Hyperkyphosis has been reported to predict mortality in an older community-dwelling population [10].

In many patients kyphosis can be attributed to anterior vertebral compression fractures, but we have previously shown that a high percentage of women have hyperkyphosis without compression fractures [11]. Milne and Lauder also noted that wedge fractures accounted for only 48% of the variation in kyphosis in women [12], and Schneider et al. noted that vertebral fractures were present in only 37% of people with the most severe kyphosis [13]. Bartynski reported severe thoracic kyphosis in older patients in the absence of vertebral fractures [14]. This suggests that aging of soft tissues may play a contributing role and that improving paraspinous muscle tone may improve postural alignment, especially in individuals without vertebral fractures. Not all forms of exercise would be expected to be beneficial in this regard. Studies by Sinaki have shown that flexion exercises of the spine tend to increase the number of vertebral fractures while extension exercises tend to be the most beneficial for prevention of fractures [15].

The question raised is whether a non-pharmacologic/ non-surgical intervention could arrest the progression of hyperkyphosis and its associated morbidity. We could find very few reports of prospective studies which evaluated the effect of specific exercises on postural alignment [15–18, 24, 25]. The purpose of this study was twofold: (1) to assess changes in spinal curves with age; i.e. the natural history of kyphosis, in the patient population attending our osteoporosis clinic and (2) to determine prospectively whether exercises designed to strengthen the extensor muscles of the spine are effective in maintaining or improving postural alignment in aging women.

Methods

The first part of this study was a cross-sectional, study of the relationship between the angle of kyphosis and age. The second part was a study of the effect of extension exercises on the progression of kyphosis over a 1-year period. Spinal curves were measured by methods described below, and spinal radiographs were taken in all women at the time of their initial visit to the Osteoporosis Clinic. Patients with vertebral fractures and/or scoliosis were excluded from the study. For part 1 of the study, the spinal measurements of the first 250 consecutive women who did not have compression fractures or scoliosis were studied retrospectively. Patients were referred to the clinic for screening because of the presence of risk factors, or because they had been found to have osteopenia or osteoporosis either by measuring bone mineral density or by x-rays suggestive of demineralization. The demographic characteristics of this patient population were previously described [11]. The following was the age distribution of these women: 19 patients 30-39 years of age, 49 patients 40-49 years of age, 81 patients 50-59 years of age, 120 patients 60-69 years of age. Cervical depth and area under the thoracic curve were plotted against age to determine relationship between the angle of kyphosis and age. All patients signed consent for their data to be used for this study, and the study was approved by the IRB of the University of Kansas Medical Center.

For part 2 of the study all women seen in our osteoporosis clinic were instructed in a set of nine exercises to strengthen the extensor muscles of the spine (Fig. 1). They were instructed to keep an exercise log, and were questioned at follow-up about which exercises were actually performed. Patients were considered compliant if they had performed both floor and elastic band exercises at least 3 times a week. They were considered non-compliant if they had not performed any of the exercises. Patients who performed only some of the prescribed exercises or were inconsistent in performing the exercises were not included in either study group. Patients were questioned separately by a nurse, physician, and physical therapist during the course of their visit, and there was a high degree of reliability in the compliance determinations made by all observers (r=.93, p<.02). Women 50–59 years of age were selected to study the effect of extension exercises on spinal curves.

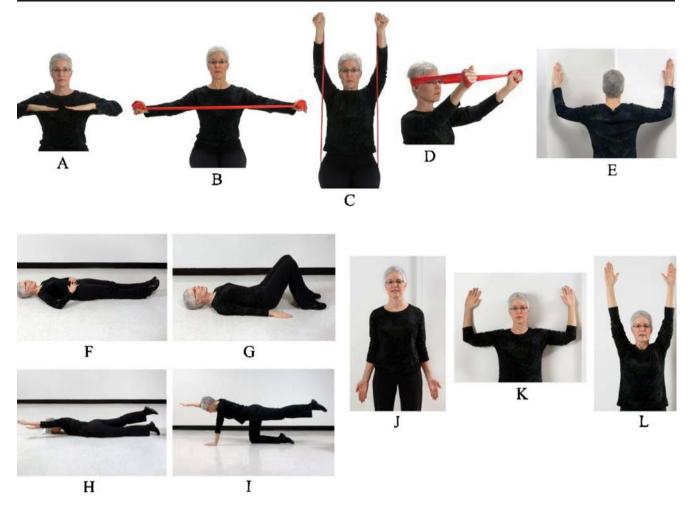


Fig. 1 Extension exercises. Nine extension exercises prescribed for all patients. Panels F and G and J, K, and L show the sequential movements of one exercise

Women 50–59 years of age were selected for the second part of the study, because the cross-sectional study suggests that the greatest change in the angle of kyphosis occurs during this decade (Figs. 2 and 3). Of the group of 81 women in this age group, 35 women had either performed the exercises consistently or not at all. Fifteen of these women complied with the exercises three times a week and 20 did not do any of the exercises. These 35 women were selected for assessment of the effect of extension exercises on the progression of kyphosis. The 46 women in the 50– 59-year age group who were excluded had performed the exercises irregularly or had performed only a few of the exercises.

Spine curves and patient height were measured by a physical therapist between 10 a.m. and 12 noon at the baseline visit and at the 1-year follow-up visit. Spine curves were determined using a posture board designed by Jessie Ball, the physical therapist in charge of the physical therapy program for the clinic at its inception. The therapist measuring the spine curves was blinded to the group to which the patient was assigned. One of three therapists,

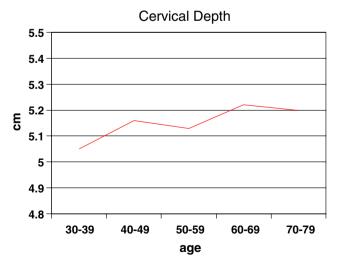


Fig. 2 Change in cervical depth (CD) with age. Change in cervical depth by decade of age expressed as mean depth in cm at each decade of age

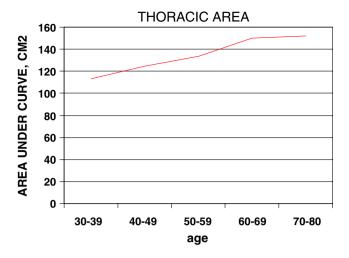


Fig. 3 Change in thoracic area (TA) with age. Change in thoracic area by decade of age expressed as area under thoracic curve in cm squared at each decade of age

who also participated in the reliability study (see below), conducted the measurements.

The posture board consists of a floor-to-ceiling $2'' \times 4''$ vertical board with three columns of holes with a vertical spacing of 2.54 cm. (Fig. 4) Moveable dowels, calibrated horizontally at .25 cm, varying in length from 23 to 46 cm, were placed in the holes. The spinous processes of the seventh cervical vertebra (C7) and the first sacral vertebra (S1) are identified by palpation and the overlying skin is marked with a felt tip pen. These serve as landmarks for the tester to determine where to begin and end measurements. The patient, with outer clothing removed, stands in her best posture with feet placed 13 cm from the board with the most medial aspects of the feet 25.4 cm apart. Strips of tape serve as reference marks for feet placement. An anti-sway device is placed in front of the patients to discourage anterior-posterior sway. This device consists of a 167.6 cm long, 5.08×10.16 cm board mounted upright to a large wooden base. A dowel is placed in horizontal holes in the upright board at the level of the patient's sternum. During measurement the dowel is placed lightly against the sternum to serve as a reference point and to discourage anterior-posterior sway.

To measure the curve of the spine, the tester pushes the pegs through the vertical board until they just touch the subjects' skin overlying the spinous processes from C7 through S1. The distance projected by each peg; that is, the distance from the pole to the spinous process is recorded to the nearest 0.25 cm and graphed on a posture evaluation form.

Height was measured between 10 a.m. and noon, using a Harpenden stadiometer mounted to the wall. Measurements were taken with the subject positioned in their stocking feet with their back to the measuring rod, heels together touching the base of the heel plate, buttocks or back touching the wall, looking straight ahead and keeping head level without tilting the chin, and assuming their best, most fully erect posture. The measurements were taken during quiet breathing and hair was compressed as much as possible.

Calculation

The cervical depth represents the greatest distance from the pole to the cervical spine. The thoracic depth is calculated by subtracting the shortest distance from the vertical board to the thoracic spine from the longest distance from the board to the cervical spine (Fig. 5). This method tends to nullify the effects of forward or backward lean of the whole body and minor aberrations in recording the whole thoracic curve. Lumbar depth was calculated by subtracting the shortest distance from the board to the thoracic spine from the longest distance from the board to the lumbar spine; this distance represents the degree of lordosis. The areas under the cervical, thoracic and lumbar curves were calculated using the trapezoid rule for estimating the area beneath the curve [19], where Y represents the distance between the horizontal pegs (2.54 cm) and X represents the respective distances from the pole to the patient's spine:

Area =
$$Y[(X_{20}/.2 + X_{21} + ... + X_{33.2}) - (34 - 20)(X_{34}/.2 - X_{20}/.2)]$$



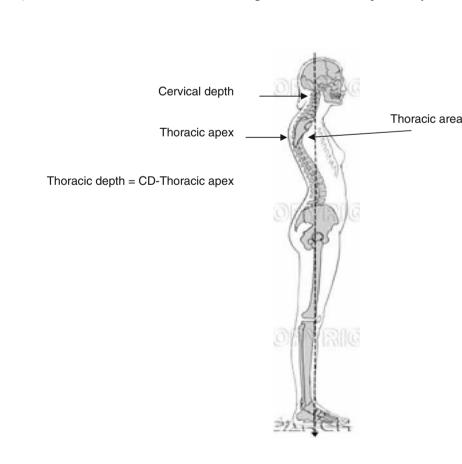
Fig. 4 Spine board. The spine board developed at the University of Kansas Medical Center. Moveable dowels are spaced 0.25 cm apart vertically and are calibrated in 0.25 cm increments

Reliability of observations

The reliability of the measurements was tested by five physical therapists who had been previously instructed in the use of the spinometer and were using the apparatus regularly in the clinical setting. Three of the therapists were those who made the measurements for this study. Each of the five therapists measured each of the three subjects three times. The subject stepped away from the board after the pegs were placed and left the room while data were recorded, returned and resumed position for the next measurement. Then a second observer entered the room and carried out the measurements on that subject. The process was repeated until all measurements were completed.

Measurements of cervical depth were reproducible with 95% confidence to 0.25 cm. Pearson's product moment correlation coefficients (*r*-values) of each set of three trials of all five therapists were determined on all subjects. The *r*-values for thoracic depth are as follows: trials 1 and 2, r=.93 (p<.02); trials 1 and 3, r=.82 (p<.05); trials 2 and 3, r=.86 (p<.02). Thus, measurement of cervical and thoracic depths were highly reproducible. Measurement of lumbar depth was less reliable. The mean of all differences in measurements of lumbar depth was .567±.460 cm. The *r*-values for lumbar depth were as follows: Trials 1 and 2, r=.82 (p<.05); Trials 2 and 3,

Fig. 5 Points of measurement. Arrows indicate the points of measurement of cervical depth, thoracic apex, and thoracic area



r=.28 (p=NS); Trials 1 and 3, r=.43 (p=NS). The coefficient of variation for height measurements was 0.9 mm (.09 cm).

The posture board measuring device was validated by comparing (using Pearson's correlation) the cervical depth and thoracic area calculated from board measurements to Cobb's angle [20] measured by the radiologist at the time of interpretation of roentgenograms of the thoracic spine. There was a significant correlation between the thoracic area calculated from posture board measurements and the Cobb's angle measured from spine x-rays, thoracic area (r=.580, p < = .0001), and cervical depth (r=.667, p=.<0001).

Statistical analyses

To test the reproducibility of spine board measurements by observers, an analysis of variance for repeated measures was carried out using the mean thoracic depth and cervical depth determined by each tester for each subject. A oneway analysis of variance for repeated measures was then used to compare the means for each subject between testers. A significance level of 0.05 was used. Pearson's product moment correlation coefficients (*r*-values) were calculated to assess reproducibility of measurements among observers, and to compare spinal curves measured using the posture board to Cobb's angle measured from spine x-rays. The

 Table 1 Baseline data for patients in compliant and non-compliant group

	Compliant	Non-compliant	p-value
Age	53.2±2.1	54.8±.59	.463
BMD g/cm ²	0.931±0.04	0.907±0.036	.665
T-score	-1.7±.38	-2.2±.29	.472

p-values represent the significance of the difference between the compliant and non-compliant groups. No significant differences were observed

significance of the change in CD, TA, and height was determined using the paired T-test. A *p*-value of <.05 was considered significant. The significance of the difference of the mean change in CD, TA and height between groups was determined using the unpaired T-test.

Results

An increase in cervical depth or thoracic area was considered to represent deterioration of posture. Conversely, a decrease in these parameters represents a decrease in the degree of kyphosis. Lumbar depth results were not reported because of lack of reproducibility of measurements.

When we analyzed the trends of the change in spinal curves with age for our entire patient population, we noted that with each decade there was an increase in cervical depth and thoracic area. (Figs. 2 and 3) The slope of the CD and TA curve plotted against age was greatest in the 50–59-year age group.

Part 2 of this study examined the effect of extension exercises on these trends in women between 50 and 60 years of age. Bone densities and age are shown for each group in Table 1. There was no difference between compliant and non-compliant groups in the baseline CD

Fig. 6 Change in cervical depth (CD). The left panel shows the cervical depth (CD) of both groups a baseline. The difference in CD between groups was not significant. The panel on the right shows the change CD after one year of extension exercises in those taking the exercises (compliant) and those who did not (non-compliant). See Results section for SEM

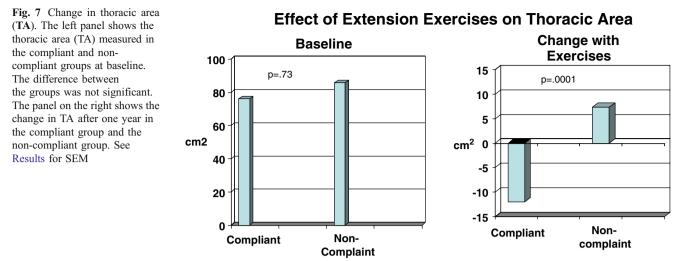
 $(6.8\pm.4 \text{ vs. } 6.05\pm.4 \text{ cm}, p=.78, \text{ respectively}), \text{ or TA } (76.6\pm.4 \text{ cm}, p=.78, \text{ respectively})$ 4.4 vs. 85.0 ± 5.4 cm², p=.73, respectively). The baseline CD and TA for the patients excluded from the study because of inconsistent exercise patterns did not differ significantly from the other two groups (CD 5.8 ± 1.6 , p=.96; TA 78±2.0 cm², p=.52). Cervical depth decreased (improved) significantly (-.89 \pm .11 cm, p=.05) in the compliant women while remaining essentially unchanged in the non-compliant group $(-.03\pm.12 \text{ cm}, \text{ NS})$ (Fig. 6). Thoracic area tended to decrease (improve) in compliant women (-12.0 ± 1.7 cm², $p\pm.016$) while increasing (worsening) significantly in non-compliant $(7.3\pm2.7 \text{ cm}^2, p=.01)$ (Fig. 7). The differences between the mean change in cervical depth and thoracic area in the compliant vs. noncompliant groups were highly significant, p < .0001 for both values. In the excluded group the mean change in CD and TA was not significant (CD $0.2\pm.03$ cm, p=.878; TA $3.5\pm$ 2.8 cm², p=.96). Height increased by $0.1\pm.05$ cm in the compliant group while decreasing $0.1\pm.06$ cm in the noncompliant group (p=.014).

Discussion

In the cross-sectional study, we observed a steady increase in cervical depth and thoracic curve in women, without compression fractures, between 40 and 70 years of age (Fig. 2). This is in accord with the observations of Milne and Lauder and Porter who found an age-related increase in the prevalence of kyphosis [12, 21]. The greatest change in the thoracic curve in our cross-sectional study was observed between the subjects 50 and 70 years of age. Cervical depth (kyphosis) increased linearly from 50 to 59 years of age. With these observations in mind, we studied the effect of spinal extension exercises on progression of kyphotic changes over a period of 1 year in

Baseline Change with excercises 12 10 0.55 p=.78 8 p=.0001 cm 6 cm 0.05 4 -0.45 2 n -0.95 Compliant Non-Compliant Noncomplaint complaint

Effect of Extension Exercises on Cervical Depth



women 50–59 years of age, which is the span when change would be expected to be most rapid.

Spinal extension exercises resulted in improvement in all measured parameters of kyphosis. The most significant effect was in the area under the thoracic area curve. Thoracic area is an accurate measure of kyphosis as illustrated by the high correlation with Cobb's angle measured on roentgenograms of the spine. The improvement in spinal alignment in women performing spinal extension exercises supports the hypothesis that an appropriate exercise program can improve and/or maintain postural alignment in many women without fractures.

Kyphosis is erroneously believed to be due to compression fractures in most cases, while, in fact, previous studies have shown that 20%–50% of patients with kyphosis do not have compression fractures [11–14]. A number of factors may increase kyphosis. Dehydration of the intervertebral discs occurs with aging. This leads to loss of elasticity and resiliency, which alters the height and shape of the disc. In addition, ligament contraction can contribute to changes in posture.

Chow and Harrison observed that people who were less physically fit and those who had experienced bone loss had a greater degree of kyphosis [17]. With progressive bone loss anterior compression fractures and wedging occurs, thus increasing the anterior bending of the thoracic spine. Posture is also affected by heredity, habit and emotional stress. The individual with poor posture slumps forward causing an exaggeration of thoracic kyphosis. Activities which call for repetitive forward curving of the spine, e.g., flexion exercises, create stress on the anterior portion of the discs and vertebral bodies possibly resulting in anterior wedging. Physical fitness has been shown to influence kyphosis with those who are most fit having the lowest degree of kyphosis [17]. Back muscles have extensive attachments to the spine and serve as extensors of the back. Strong back muscles are better able to counteract the anteriorly directed gravitational pull on the thoracic spine. It is not surprising that exercises aimed at strengthening extensor muscles would decrease the angle of kyphosis.

Several non-surgical interventions to treat/prevent kyphosis have been studied. The first publication on back extension exercises was by Sinaki [22]. The use of spinal orthosis to improve trunk muscle strength was shown to decrease the angle of kyphosis [23]. In a study reported by Itoi, back strengthening exercises performed by postmenopausal women did not produce overall differences in either back strength or kyphosis, but women with significant kyphosis and the greatest increase in back-extensor strength experienced a 2.8 degree decrease in the angle of kyphosis [24]. Yoga exercises for three months in women with hyperkyphosis resulted in improved physical function without improvement of the angle of kyphosis [18]. Older adults with impaired cardiorespiratory fitness were enrolled in a program which compared spinal flexibility exercises plus aerobic training with aerobic training alone. There was no added benefit of spinal flexibility training on kyphosis [16]. Low-intensity back exercises which strengthened extensor muscles have been shown to improve quality of life, and when a 4-week spinal proprioceptive extension exercise program was combined with spinal weighted kypho-orthosis, improvement in balance, gait and risk of falls was observed [25, 26]. One of the major problems with all of these studies is that most, with the exception of the carefully executed study of Itoi and Sinaki [24], were of short duration, and in several, there was lack of emphasis on extension exercises.

Progression of kyphosis is probably not preventable in women with scoliosis, severe anterior wedge vertebral fractures, or severe degenerative spine disease. Our results are applicable only to relatively healthy women who are free of significant abnormalities of the spine. There are conditions in which extension exercises should be avoided, such as in patients with symptomatic spinal stenosis.

There are several problems with the study reported here. This was a descriptive study, not a formal interventional trial. Other exercise programs or occupational and leisure activities in which the subjects participated were not taken into account. Contributing conditions related to compliance and non-compliance may have altered results. Women who chose to do the exercises regularly may have been those who were generally more active, more fit, had better posture and generalized muscle tone, and found it easier to do the exercises. This may have selected women for the compliant group who were already least likely to experience deterioration in spinal curves over the year of observation, while non-compliant women may have represented those who were less active and more likely to experience deterioration. However, at baseline, there was no difference between groups in the degree of kyphosis, suggesting that there was no marked difference in posture at the beginning of the study. Compliance remains a problem. Only 18% of the 81 patients in the 50-59-year-age group performed the exercises regularly; however, we defined compliance rather rigidly. Patients were considered compliant if they had performed both floor and elastic band exercises at least three times a week. The change in CD and TA in the group excluded because they occasionally or inconsistently performed the exercises was comparable to the changes observed in the non-compliant group. All things considered, the improvement in posture and increase in height observed in the compliant group suggests that the exercises, regardless of baseline motivation and fitness, contributed to the prevention of the deterioration that was observed in the non-compliant group.

In future studies x-rays should be obtained at the end of the year of exercises to determine whether any of the subjects had sustained a fracture and to compare Cobb's angle with posture measurements.

Many questions remain that can be answered only by a randomized prospective study of several years duration. The effect of spinal extension exercises on posture in women with fractures remains unknown. The long-term effect of this exercise program requires further study to determine whether the effects that we observed over 1 year can be sustained and whether women can be motivated to continue such a program over a number of years.

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